ARM Progress Report 2000

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Continuation of Data Analysis Software Development for the Atmospheric Emitted Radiance Interferometer (AERI)

DOE Award DE-FG-02-98ER61365

Scientific Goals:

Routine specification of cloud and atmospheric radiative properties, the thermodynamic structure of the PBL, and the entire troposphere where GOES and TOVS data is available, will be conducted at the SGP, TWP, and NSA ARM sites through the amalgamation of AERI with other appropriate data. The objectives can be classified into two broad categories: (1) clear sky and (2) cloudy sky. Clear sky science objectives of this proposal are: (i) to improve radiative transfer calculations for the molecular atmosphere, and (ii) to improve the retrieval of the temperature and moisture profile of the Planetary Boundary Layer (PBL) which is needed to determine the surface heat budget for single column model validation and assimilation. The key objective of AERI cloud radiance data analysis is the development of parameterizations that relate weather and climate model variables (e.g., temperature and relative humidity) to cloud surrogate variables from which the cloud radiation can be specified.

Accomplishments:

- Provided an AERIplus retrieval algorithm update to the Pacific Northwest National Laboratory (PNNL), this update included improving the first guess temperature and moisture by using GOES sounder retrieval upper tropospheric temperature and moisture

- Provided AERIplus retrievals to Ric Cederwall from the Spring 1999 single column model IOP. The AERIplus retrievals were performing equivalent to radiosonde data for driving the single column model during clear and partly cloudy periods.
- Developed a visualization algorithm using VisAD to interpret the temperature, moisture and wind fields at all five AERI and wind profiler locations within the SGP CART site domain.
- Combined the AERIplus temperature, moisture, and wind fields to produce estimates of moisture flux divergence/convergence in preparation for SCM validation. A case study from the May 3, 1999, tornado outbreak provided a new interpretation about the thunderstorm initiation processes.
- Prepared a paper with Dave Turner and Rich Ferrare evaluating the AERIplus moisture retrieval accuracy as compared to Raman Lidar and radiosondes which was published in the Bulletin of the American Meteorological Society (BAMS).
- Processed a Surface Heat Energy Budget of the Arctic (SHEBA) AERI data set for the University of Colorado (Dr. Judy Curry) to provide high time resolution temperature profiles of the boundary layer for Large scale Eddy Simulation (LES) studies and validation.

Progress:

Important progress has been made towards the goals funded under DOE Award DE-FG-02-98ER61365. The primary emphasis on this funding period was AERI temperature and water vapor retrieval improvement and update, single column model sensitivity studies using the retrievals, heat/moisture flux calculation using the retrievals from all five AERI sites in the SGP CART domain, and manuscript preparation.

I. AERI temperature and water vapor retrievals

The AERI temperature and water vapor retrieval algorithm was updated at PNNL. Improvements include implementation of hourly GOES retrievals into the first guess profile to allow for full tropospheric retrieval of temperature and moisture. Currently the Rapid Update Cycle (RUC) numerical model profiles are archived in real time to improve the first guess temperature (since GOES used the ETA model temperature) and provide water vapor profile first guess profiles when GOES data are unavailable (due to clouds or data eclipses). The RUC model initial guess field has superior temperature profiles because it assimilates temperature information from Automated Commercial Aviation ReportS (ACARS) data every three hours rather than the twice daily update provided to the ETA model. The incorporation of the RUC data is already running in real time at the University of Wisconsin – Madison (http://zonda.ssec.wisc.edu/~waynef) and will be provided to PNNL within the next funding period. This new product is called AERIplus retrievals since a hybrid first guess created from satellite, numerical model, and climate statistics is used to provide the physical retrieval with the best estimate of thermodynamic state before the AERI radiance observation is satisfied.

AERI/GOES moisture and retrieval validation was conducted and published by comparing the AERI retrieved moisture profiles to the Raman Lidar and radiosonde data at the SGP CART site. Fractional water vapor differences between the Raman Lidar and AERI/GOES retrievals within the boundary layer were determined to be 5% at night and 10% during the day (Turner et al. 2000). Several case studies indicate good correlation between the passive and active remote sensing systems. AERI/GOES temperature profiling accuracy within the boundary layer indicated differences of less than one degree between the AERI and collocated radiosondes (463 matches).

The retrieval algorithm has also been modified to allow time for interpolated radiosonde data to be used as a first guess for the Surface Heat Energy Budget of the Arctic (SHEBA) AERI data set since a large database of radiosondes is not available to develop a statistical first guess. Two days of processed AERI retrieval data was delivered to Dr. Judy Curry at the University of Colorado to provide high time resolution profiles of the PBL for LES model validation.

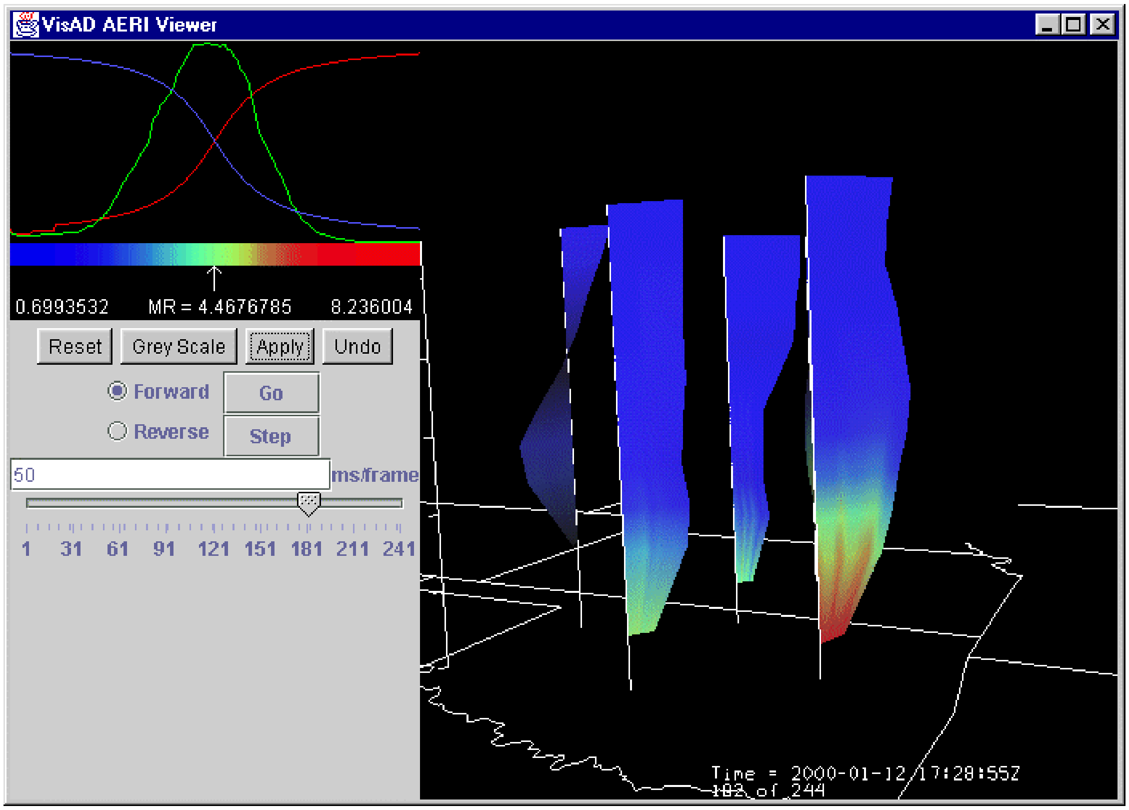
II. Single Column Model Sensitivity Studies

A variational analysis sensitivity study was conducted by Shaocheng Xie and Ric Cederwall to study the impact of replacing radiosonde data with AERI/GOES retrieval profiles and wind profiler data. The goal is to drive the SCMs between Intensive Operational Periods (IOPs), when radiosondes are launched less often or not at all. Retrievals were processed for the March 1999 SCM IOP. Preliminary indications are that the AERI temperature and moisture information within the boundary layer is relatively accurate; however, large bias in temperature within the GOES profile above the boundary layer needs to be addressed. The temperature bias resulted from the ETA model temperature profile and has been addressed by implementing the RUC temperature profile within the first guess. More information can be found at http://dev.www.arm.gov/docs/scm/sounding_retrieve/poster.html. Currently work is being done to automate the Single Column Model (SCM) runs using a combination of the remote sensing and in situ data.

III. Visualization and Atmospheric Flux

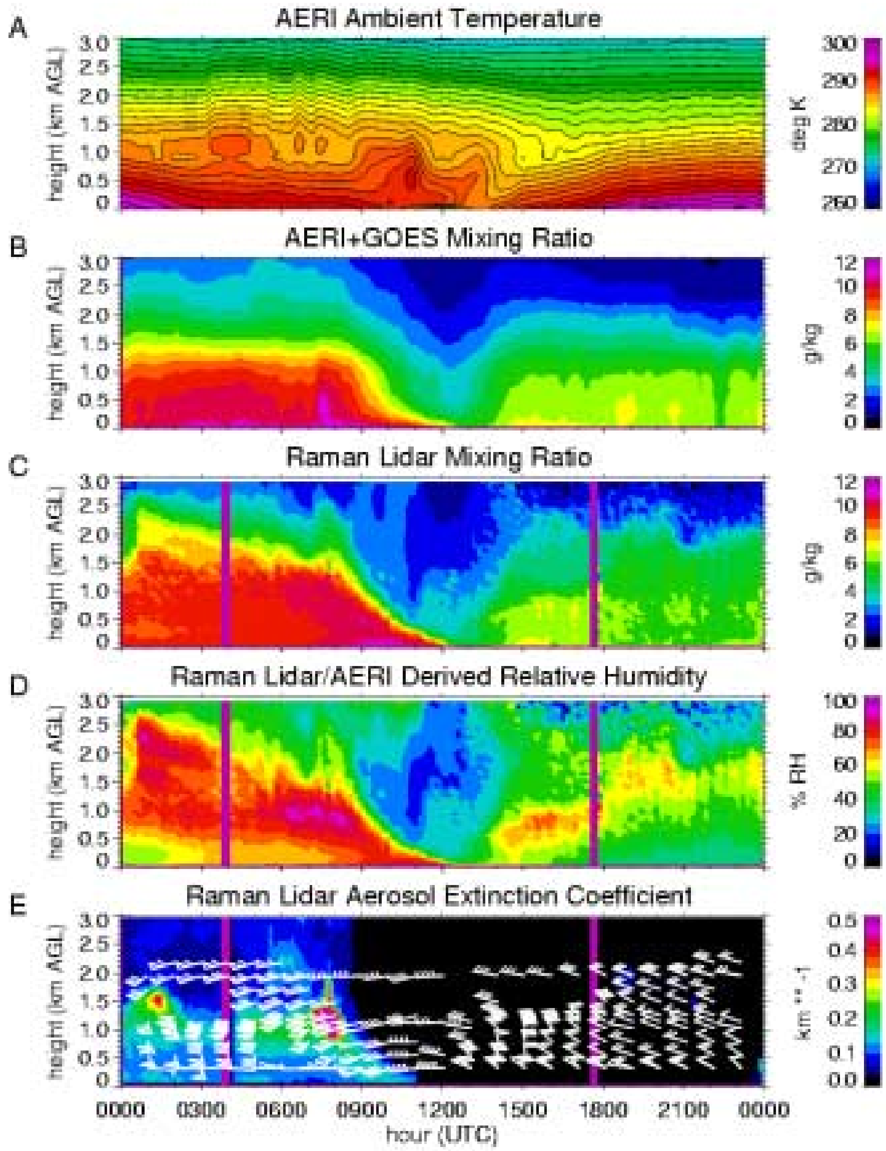
Preliminary work has been conducted to incorporate the five AERI system temperature and moisture fields and collocated wind profiler data into a powerful visualization tool called VisAD. This java based visualization tool allows the scientist to analyze the data sets together in a cohesive package, providing more information then looking at each independently. Meteorological processes such as moisture and heat flux convergence can be rapidly calculated and visualized from the remotely sensed data sets. Direct comparison of this data to Single Column Model output in four dimensions is easily done with this system. Examples of “moisture return flow” detected with the AERI and wind profiler systems are attached. Derived meteorological fields from remotely sensed and in situ data set, and direct comparison to Single Column Model, output is an important evaluation method useful to the ARM community.

Figures:



Feltz (Co-PI) and Knuteson (PI), UW-Madison SSEC, 2000

Figure 1: An example of VisAD visualization of AERI/GOES water vapor retrievals at each SGP CART site represented as flags. Wind profiler vectors determine the length and direction of each flag for a one-hour period. The AERI water vapor profiles are at ten-minute resolution. A frontal passage is noted in western Oklahoma with the strongest moisture advection (8 g/kg per legend) in eastern Oklahoma ahead of the front. VisAD (developed at UW-Madison Space Science Engineering Center) is a very capable tool for doing meteorological analysis of data and numerical model fields.



Turner, Feltz, and Ferrare, (PNNL, UW-Madison, and NASA Langley), 2000

Figure 2: Time-height cross section of ambient temperature derived from the AERI (A), water vapor mixing ratios derived from the AERI+GOES (B) and Raman lidar (C), relative humidity derived using AERI temperature and Raman lidar mixing ratio data (D), and aerosol extinction from the Raman lidar for the 13 April 1998 dryline case. Wind data from a collocated 915 MHz wind profiler is over plotted on the aerosol data. Both the AERI+GOES and the Raman lidar retrievals are at 10-min resolution. A synoptic dryline passage is very evident between 0800 and 1200 UTC as a gradual drying from 2 km to the surface (panels B and C) correlated with a westerly wind and reduction in aerosol amount in panel E. AERI+GOES retrievals have been compared to both Raman Lidar and radiosondes for validation (Turner et al. 2000).

Refereed Publications:

Feltz, W. F., and J. R. Mecikalski, 2000: Nowcasting Convective Initiation Using the Ground-Based Atmospheric Emitted Radiance Interferometer (AERI) Case Analysis: The 3 May 1999 Oklahoma Tornado Outbreak. *Weather and Forecasting,* In review.

Schmit, T. J., W. F. Feltz, W. P. Menzel, J. Jung, J. P. Nelson III, and G. S. Wade, 2000: Validation and Use of GOES Sounder Moisture Information. *Bull. Amer. Meteor. Soc.,* In review.

Turner, D.D., R. A. Ferrare, L. A. Heilman, W. F. Feltz, and T. P. Tooman, 2000: Automated Retrievals of Aerosol Extinction and Backscatter Coefficient Profiles from a Raman Lidar. *J. Appl. Meteor.* In review.

Turner, D. D., W. F. Feltz, and R. A. Ferrare, 2000: Continuous Water Profiles from Operational Ground-based Active and Passive Remote Sensors. *Bull. Amer. Meteor. Soc*., **81**, 1301-1317.

Smith, W.L, W.F. Feltz, R.O. Knuteson, H.E. Revercomb, H.B. Howell, and H.M. Woolf, 1999: The retrieval of planetary boundary layer structure using ground-based infrared spectral radiance measurements. *J. Atmos. Oceanic Technol.,* **16,** 323-333.

Conference Publications:

Feltz, W. F., R. O. Knuteson, H. E. Revercomb, H. B. Howell, W. L. Smith, and D. Turner, 1999: Atmospheric Emitted Radiance Interferometer (AERI) temperature and water vapor retrievals for the ARM Program. Conference on Atmospheric Radiation: A Symposium with tributes to the works of Verner E. Suomi, 10th, Madison, WI, 28 June-2 July 1999 (preprints). Boston, MA, American Meteorological Society, pp 426-429.

Feltz, W. F., R. O. Knuteson, H. B. Howell, B. Hibbard, T. Rink, T. Whittaker, D. D. Turner, S. Xie, and R. T. Cederwall, 2000: Retrieval and Visualization of AERIplus Temperature and Moisture Profiles for Assimilation into ARM Single-Column Models. Proceedings of the Tenth Atmospheric Radiation Measurement (ARM) Program Science Team Meeting. San Antonio, Texas, March 13-17, 2000.

Knuteson, R. O., F. A. Best, W. F. Feltz, R. G. Garcia, H. B. Howell, H. E. Revercomb, D. Tobin, and V. Walden, 1999: UW High Spectral Resolution Emission Observations for Climate and Weather Research: Part II Groundbased AERI. Conference on Atmospheric Radiation: A Symposium with tributes to the works of Verner E. Suomi, 10th, Madison, WI, June 28-July 2, 1999 (preprints). Boston, MA, American Meteorological Society.

Knuteson, R. O., H. B. Howell, H. E. Revercomb, R. Dedecker, and D. Tobin, 2000: AERI's for ARM: Accuracy and Applications. Proceedings of the Tenth Atmospheric Radiation Measurement (ARM) Program Science Team Meeting. San Antonio, Texas, March 13-17, 2000.

Initiatives for One Year Renewal
Continuation of Data Analysis Software Development for the Atmospheric Emitted Radiance Interferometer (AERI)

I. AERIplus Retrieval Improvements

The AERI retrieval profile vertical levels within the boundary layer will be increased by a magnitude of order to help resolve vertical gradients of temperature and moisture within the boundary layer over the North Slope of Alaska site. Specifically a 200 level fastmodel has been developed from Tony Clough's Line-By-Line Radiative Transfer Model (LBLRTM) with the latest Hitran transmittance coefficients. This should improve the accuracy and resolution of the AERI retrievals within the PBL. The algorithm will also include the aforementioned (within the progress report) hybrid first guess improvement (included RUC2 numerical model initial state within the first guess). This code will be implemented at the Pacific Northwest National Laboratory (PNNL) to be applied to all AERI data sets including SGP CART, NSA, TWP, and SHEBA. Special attention will be placed on the Nauru 1999 datasets collected by the University of Miami M-AERI systems and the TWP AERI system.

Assessment of driving Single Column Model's (SCM) with remotely sensed data will continue with strong collaboration with Cederwall and Xie at Lawrence Livermore National Laboratory (LLNL).

II. Automation of AERI Retrieved Cloud Optical Depth

Data from AERI, micro-pulse lidar (MPL), and radiosonde launches are combined to derive cirrus cloud optical depth for a series of 18 AERI spectral micro-windows. This process will be automated using data cases that consist of single cloud layers, determined from the MPL cloud boundary data product. The process will include: line-by-line radiative transfer model (LBLRTM) calculation of column transmittance for each CART radiosonde; interpolation of LBLRTM transmittance and radiosonde measured temperature to AERI scene times; and determination of average cloud boundaries from MPL data. Given this information, the infrared radiative transfer equation can be inverted to yield cloud optical depth for each AERI spectral microwindow. Successful monitoring of this data product in-house will demonstrate feasibility for future inclusion in ARM data stream as a value added product (VAP). With collaboration with Dr. Bryan Baum realistic scattering properties for the 8-12 micron range will be implemented in the algorithm.

III. Infrared Flux Calculations

Comparison between AERI integrated radiances and pygeometer measurements will be conducted. Evaluation of Rapid Radiative Transfer Model (RRTM) results (which have been implemented in many climate and numerical weather prediction models) with integrated LBLRTM calculations will analyzed by Tony Clough et al. This should lead the way to improved radiative transfer within General Circulation Models (GCM's) and Single Column Model's (SCM).